

Neuropsychological Functioning and Posttraumatic Stress Disorder: Implications for War-Zone Veterans

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Austere and stressful circumstances, including exposure to horrific and life-threatening situations, typically characterize war zones. Both human and animal studies have provided considerable scientific evidence that exposure to extreme stress of the type encountered in war zones can lead to adverse neurobiological and psychological sequelae, including pronounced psychiatric symptoms and maladaptive behavioral changes. Unfortunately, it is becoming increasingly apparent that the consequences of war and other psychological trauma can extend well beyond classic psychiatric symptoms to include other types of health-related

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and psychosocial problems. Neuropsychological functioning encompasses cognitive (e.g., memory, attention, and reasoning), perceptual-sensory-motor (e.g., motor speed), and emotional (e.g., mood) behaviors thought to reflect brain integrity. In this paper, we discuss the neuropsychological correlates of trauma exposure, particularly among war zone veterans, and the implications of these findings for prevention, health care, and the research agenda. Specifically, this paper reviews the occupational and functional consequences of trauma exposure and describes both the arguments supporting and factors limiting the implementation of neuropsychological screening assessments as standard health surveillance among military populations.

Epidemiology of trauma exposure and PTSD

Psychological trauma is typically defined as an experience that poses a serious threat to the life or physical integrity of the individual or someone close to him or her. Trauma of this nature is often accompanied by an intense emotional reaction. Examples include physical and sexual assault, child abuse, fires and other natural disasters, terrorist attacks, life-threatening accidents, community violence, and military combat. At least one out of two people will be exposed over the course of their lifetimes to a psychologically traumatic event, and over half of those exposed to psychological trauma will be exposed to multiple traumatic events.¹ The rate of exposure increases in populations at high risk, such as military personnel deployed to war zones.

Exposure to psychological trauma results in a physiological and psychological stress response thought to be immediately adaptive during life-threatening situations. This response helps the organism take appropriate action and therefore enhance the odds of survival. Posttraumatic stress disorder (PTSD) can occur, however, when acute stress responses occurring in the immediate context of the life-threatening situation endure after the threat is removed and become chronic symptoms. The symptoms of PTSD include re-experiencing of the trauma (e.g., nightmares, intrusive thoughts), avoidance of thoughts and environmental stimuli reminiscent of the trauma, emotional “numbing”, and increased incidence of arousal (e.g., difficulties with sleep, exaggerated startle). The lifetime prevalence of PTSD in the adult U.S. population has been estimated to be 6.8%, with the 12-month prevalence rate estimated to be 3.6%.^{1,2} PTSD occurs much more frequently in populations in which trauma exposure is more common and severe, such as war-zone veterans. For example, a recent re-analysis of the National Vietnam Veterans Readjustment Survey yielded a conservative estimate that 18.7% of Vietnam veterans experienced PTSD at some point in their lives, and 9.1% met criteria for current PTSD over ten years after their war-zone service.³ Although not derived from population-based samples, recent screening estimates of current PTSD among Iraq War veterans have suggested that over 12% of veterans of contemporary war zones experience clinically significant posttraumatic stress symptoms within the first 90 days of their return⁴, with the prevalence of the disorder increasing over time⁵.

Neuropsychological functioning and PTSD

Subjective complaints of cognitive impairment among those affected by exposure to severe stress are not uncommon, as reflected by the integration of attention and memory abnormalities into the PTSD diagnostic criteria. These symptoms include poor concentration, "hypervigilance" (i.e., enhanced attention) to threat, intrusion of distressing trauma-related memories into conscious thoughts and dreams, and psychogenic amnesia (i.e., certain aspects of the traumatic event cannot be readily recalled). These clinical expressions of cognitive abnormalities are echoed within two bodies of scientific research involving humans. In one area of research, studies have documented how people experiencing PTSD preferentially process trauma-relevant information as compared to information not perceived to be threatening. In the second research domain, observational studies have revealed performance decrements on specific types of emotionally neutral neuropsychological tasks. Not reviewed in this paper, but also of relevance, is a large body of analog research conducted with animals that suggests at least transient changes in learning and memory following stress exposure. We focus below on the evidence derived from studies involving humans exposed to traumatic events.

Information processing biases

Consistent with the clinical phenomenon of hypervigilance to potential environmental threat, PTSD is associated with biases in how threat-relevant information

is processed.⁶ People with PTSD are more likely to attend to, and to remember, trauma-relevant information than other types of information that is less personally threatening.^{7, 8} There also is preliminary evidence that individuals with PTSD are biased to interpret emotionally ambiguous information as threatening under certain conditions.⁹

The tendency in PTSD to attend to threat-relevant information has been especially well documented using an experimental paradigm known as the emotional Stroop task. The emotional Stroop task involves performing a perceptual task (i.e., naming the color of ink in which a word is printed) when the semantic content of words is potentially distracting because of their emotional relevance. Individuals with PTSD typically name the color of ink in which trauma-related words are presented more slowly than they color-name emotionally neutral or trauma-irrelevant word.¹⁰ The slowed color-naming performance of individuals with PTSD is interpreted as reflecting greater interference imparted by the threat value of these words. The experimental finding of attentional bias resembles very closely the distraction that people with PTSD report when they are confronted with elements in their immediate environment or internal thoughts that remind them of the trauma.

Although not as extensively studied, there is also evidence of threat-relevant anterograde memory biases in PTSD. Anterograde memory refers to the process of learning and remembering new information. When presented with words that vary in their threat-relevance, trauma-exposed individuals with PTSD show enhanced recall of the trauma-related words whereas

those without PTSD do not. This finding is especially true when memory is tested with free recall tests (i.e., recall without prompts).¹¹ On memory tasks that require recall of a person's prior life events (i.e., autobiographical memory tasks), individuals with PTSD produce "overgeneral" memories in which they recall only broad categories of events, rather than specific detailed accounts of life events.^{11, 12}

When placed within an evolutionary context, information processing biases to threat-relevant information are initially adaptive. The cognitive capacity of any individual is limited, leading to ongoing prioritization of cognitive effort and resources. What this means is that we cannot attend to, or process with equal effort, all possible stimuli or events in our environments. How we allocate cognitive resources can therefore influence survival when we are confronted with life threat. In a potentially dangerous situation, it could be argued that survival will be enhanced if the source of danger is held in focus enough to take appropriate action. Selective memory of information relevant to previous threats can likewise help influence future behavior if the individual is again confronted by the threat. Unfortunately, initially adaptive cognitive responses to threats may be perpetuated beyond dangerous contexts and crossover to normal life. In the case of PTSD, this occurs even when such thought processes are no longer necessary and instead have become maladaptive.

Neuropsychological Abnormalities on Emotionally Neutral Tasks

Examination of neuropsychological abnormalities on emotionally neutral tasks remains a developing area of research. Learning, memory, attention, and intellectual functioning have been among the most commonly studied neurocognitive domains in PTSD samples, with learning and memory studies constituting the largest proportion of these studies.¹³ Overall, this growing body of research indicates that PTSD is associated with mild deficits on learning and memory tasks, especially during the initial acquisition phases of learning, on tasks assessing specific components of attention, and on intellectual tasks assessing verbal abilities.¹⁴ This emerging field is not without controversy, however, and some studies have not found neuropsychological abnormalities specific to PTSD.¹⁵⁻¹⁷

Nevertheless, the evidence for anterograde memory dysfunction in PTSD is robust. A recent meta-analysis that aggregated data from more than 1,400 participants provided strong evidence that PTSD, as compared to the absence of PTSD comparators, is associated with less proficient memory for emotionally neutral material.¹⁸ Despite considerable variability between studies, both civilian and military samples of adults with PTSD showed a consistent decrement in memory performance that was small to moderate in magnitude and concerned primarily with verbal rather than visual memory. Examination of concurrent conditions revealed that PTSD-related memory deficits could not be attributed to head injury, a condition with particularly high relevance to

Iraq War veterans due to their elevated risk of exposure to road bombs and other blasts resulting in concussive injuries.¹⁹⁻²⁰

There is also significant evidence of attentional impairment associated with PTSD. In particular, PTSD has been associated with performance deficits on tasks that require working memory (i.e., the ability to manipulate information mentally) or the ability to maintain optimal levels of vigilance consistently over a prolonged interval ("sustained attention").¹⁹⁻²¹ In contrast, other aspects of attention, such as the ability to shift focus, appear impervious to PTSD.²¹ Interestingly, PTSD has been associated with cognitive disinhibition and commission errors across both attention and memory tasks, a pattern collectively suggestive of a failure to screen out task-irrelevant information.¹⁹ Such a cognitive gating failure can be invoked to explain the failure to inhibit unwanted and distressing re-experiencing of the trauma, one of the hallmark symptoms of PTSD. In other words, people with PTSD are not always able to ignore upsetting information related to their trauma experiences.

Although few studies have comprehensively measured intellectual functioning in PTSD, those that have suggest that individuals without PTSD as compared to trauma-exposed individuals with PTSD tend to perform better on IQ tests, especially on those assessing verbal skills.^{17, 20, 22-24} The dissociation between verbal and visuo-spatial performances on intellectual tasks²⁵ mirrors the pattern of relative verbal weaknesses on learning and memory tasks, pointing to potential functional brain asymmetries in the direction of the left cerebral hemisphere being relatively less activated than the right.

Neuropsychological Functioning, Stress, and the Iraq War

There is currently little published work addressing the neuropsychological outcomes of the Iraq War; however, we have recently published the results of a large scale study examining neuropsychological outcomes of contemporary war-zone participation.^{26, 27} In this study, we used prospective methodology to document changes occurring from pre-deployment to post-deployment among over 600 Iraq-deployed Army soldiers and a comparable group of over 300 non-deployed Army soldiers. The results indicated that deployment to Iraq was associated with performance disadvantages on objective tests of learning, memory, and attention, and performance advantages on a test of simple reaction time. There is an elevated risk of concussive brain injury associated with deployment to Iraq; however, examination of the potential contributions of brain injury to the neuropsychological findings revealed that the findings could not be explained by deployment-related brain injury. Although PTSD symptoms could similarly not explain the deployment-related findings, the results are consistent with the pattern that might be expected to accompany a neurobiological stress response. The pattern of results suggested to us that the neuropsychological findings represented an arousal-based stress response that precedes PTSD symptoms but that may eventuate in PTSD if perpetuated.

Cognitive deficits and PTSD: Functional implications

In considering the clinical significance of neuropsychological abnormalities associated with war-zone stress and PTSD, the potential impact of cognitive impairment on daily functioning is the correlate of PTSD that is perhaps of greatest relevance to the individual and to society. Evidence that PTSD leads to decreased occupational functioning³⁰, reduced quality of life³¹, and increased health risk^{32,33} is accumulating. Although little work has been done to assess the specific functional impact of cognitive abnormalities in PTSD, cognitive impairment has potential to negatively impact work performance and other aspects of quality of life.

Cognitive deficits, for example, have been associated with negative employment outcomes following brain injury³⁴, including high rates of unemployment^{35,36}, frequent termination from jobs, and decreased work efficiency³⁷. Schizophrenia studies have similarly revealed that neurocognitive functioning exerts a more potent effect on work capacity than do the more overt and often salient psychiatric symptoms associated with the disorder³⁸. Even in healthy populations, cognitive impairment negatively affects occupational functioning via mechanisms such as reduced performance efficiency, compromised decision-making, distractibility, and increased error rates³⁹⁻⁴⁴.

As a correlate of the potentially chronic neurobiological abnormalities associated with the stress response, neuropsychological deficits may also reflect a prodrome or surrogate for stress-related somatic ill-

nesses. For example, allostatic load models of disease hold that an organism adapts to stress by directing energy to achieve biological stability. After going through repeated cycles of such adaptation, there can be a physiological cost, including the failure to “shut off” certain neurobiological responses that, when prolonged, can result in decreased immunity, tissue injury, and other adverse physiological effects such as elevated blood pressure and hormonal disruption⁴⁵. If neuropsychological impairment indeed reflects neurobiological dysfunction associated with adaptation failures, these neuropsychological deficits may indicate the initial progression to a much more extensive array of health problems than cognitive compromise alone.

Cognitive deficits and PTSD: Policy implications

Healthcare, prevention, and surveillance in military and military veteran populations

The potential implications of neuropsychological compromise to the health and functioning of war-zone veterans suggests that neuropsychological screening assessments could be an important addition to standard health surveillance among military populations. In addition to the relevance of neuropsychological functioning to stress-related conditions, neuropsychological functioning is also sensitive to other potential deployment exposures such as some classes of environmental hazards and traumatic brain injury. An additional advantage of neuropsychological assessments as a measure of brain integrity is that they

can be conducted without physical discomfort, invasive methods, or expensive technology. Moreover, neuropsychological functioning can be measured using standardized, performance-based instruments that result in reliable and objective measurement. The neuropsychological assessment process is therefore a safe, portable, reliable, and cost-effective means of estimating neural health.

There are currently several limiting factors to the widespread implementation of standard neuropsychological surveillance in military and military veteran populations. First, neuropsychological evaluations can be time-consuming and may therefore be limited in feasibility, especially in times of increased demands on military personnel. Screenings are a viable alternative; however, the field is at a point of development in which significant work still needs to be done to assess the diagnostic efficiency of neuropsychological screening evaluations against more comprehensive "gold-standard" assessments in healthy, military populations⁴⁶. A second and related impediment is that databases providing population-based normative data on neuropsychological screening batteries are scarce, making it difficult to effectively and appropriately interpret data derived from screening batteries. Finally, the widespread use of neuropsychological screenings implies the existence of an infrastructure, including sufficient healthcare providers with neuropsychological expertise that can handle referral of positive screens to the subsequent levels of assessment and/or intervention. The large potential gains in prevention and healthcare that can be realized through the implementation of neuropsychological screening, combined with the large numbers of currently deployed

service members, highlight the immediate need to develop the appropriate normative work and healthcare infrastructure to facilitate clinically meaningful neuropsychological surveillance.

Implications for PTSD treatment research

There is a growing trend in treatment outcome and clinical trials research to define outcomes more broadly than symptom alleviation. Given the practical implications of neuropsychological integrity on day-to-day functioning, neuropsychological measures are a potentially valuable ancillary index of treatment success. Measurement of neuropsychological functioning as a treatment outcome may be especially relevant among returning veterans with polytrauma conditions, many of which involve both PTSD and traumatic brain injury. Similarly, inclusion of neuropsychological and information processing measures can inform mechanistic intervention research with relevance to both the neural substrates and cognitive mechanisms underlying the clinical expression of PTSD.

Neuropsychological assessment also has the potential to be used to examine individual differences as predictors of treatment response, adherence, and completion. Although treatments might show generally positive efficacy across large groups of people, not all individuals respond to treatments similarly. Biological variation (reflected in neuropsychological measures) may interact, for example, with psychopharmacological interventions in determining outcomes. Similarly, certain psychological interventions, particularly those with strong cognitive components

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(e.g., cognitive processing and cognitive-behavioral interventions), may be more or less effective depending on the cognitive strengths and weaknesses of the individual. Certain types of cognitive deficits, such as forgetfulness, could potentially affect adherence to many different types of treatment. Therefore, the effectiveness of a number of interventions will potentially be enhanced with memory aids, suggesting the need for systematic research targeting protocol modifications that will increase adherence to, and completion of, promising interventions via improving memory. To our knowledge, inclusion of cognitive predictors of treatment response is a vastly understudied area that has significant potential to contribute to optimized service delivery.

Conclusions

In summary, it has become increasingly clear that war-zone participation and other exposures to extreme stress can result in an array of psychiatric symptoms and functional impairments, including neuropsychological abnormalities. PTSD-related neuropsychological dysfunction highlights the breadth of stress-related sequelae and underscores the importance of looking beyond emotional distress in trauma-exposed individuals. Because of the direct relevance of neuropsychological functioning to occupational performance and other aspects of daily living, neuropsychological assessment is a potentially important healthcare tool that can be used to assist in recovery and treatment efforts. Specifically, neuropsychological assessment can help guide providers in their decisions about whether to initiate ancillary health care services

such as cognitive and vocational rehabilitation, or whether modification of standard PTSD treatments is needed to accommodate any cognitive limitations. Finally, as a cost-effective indicator of brain integrity and cognitive resources, neuropsychological assessment stands to inform neurobiological and cognitive models of PTSD, contributing knowledge regarding mechanisms of treatment and which individuals might best benefit from various available treatment options. ▲

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